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ABSTRACT

The Program for Leadership in Earth Systems Education (PLESE), a teacher enhancement program sponsored by the National Science Foundation in 1990-94, was a coordinated effort to infuse Earth Systems concepts throughout the K-12 science curriculum across the United States. Characteristics of the program are reviewed in this paper and the results of evaluation of its components are discussed. Research on total program impact while still at the "immediate posttest" stage indicated substantive curriculum restructure in progress in the home schools/districts of some participating teachers. (Author)

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SCIENCE IS: UNDERSTANDING PLANET EARTH (Paper #2)

Infusing Earth Systems concepts throughout the curriculum

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Abstract. The Program for Leadership in Earth Systems Education (PLESE), a teacher enhancement program sponsored by the NSF in 1990-94, was a coordinated effort to infuse Earth Systems concepts throughout the K-12 science curriculum across the United States. Characteristics of the program are reviewed in this paper and results of evaluation of its components are discussed. Research on total program impact, while still at the "immediate posttest" stage, indicates substantive curriculum restructure in progress in the home schools/districts of some participating teachers.

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Restructuring the science curriculum.

Numerous efforts are underway in the 1990s to restructure science education in response to growing concerns that the existing "layer cake" (discipline-ordered) approach to science lacks relevance to students, prepares them poorly in life skills that demand science literacy, leaves US students lagging on standardized international tests of science knowledge, and ignores or perhaps even perpetuates naive conceptions in science. The primary efforts to change these patterns have emerged from and had the support of national organizations in science and education:

- Project 2061 (AAAS, 1989) is supported by the American Association for the Advancement of Science (AAAS). Through its book *Science for All Americans* and the associated science discipline booklets detailing background information, this project identified science concepts that every high school graduate in the United States should know. Major contributions of this effort include the idea that "less is more," or a curriculum that deals with fewer concepts in greater detail is preferred over the traditional vocabulary-laden mini-college courses common in US secondary schools. Follow-up work through selected school districts has produced several models for implementing the curriculum changes implied by 2061, and has resulted in a set of *Benchmarks* for designing the course sequences and gauging the progress of students in science through their school careers.

- Scope, Sequence and Coordination (NSTA, 1992) was an effort of the National Science Teachers Association to outline a science curriculum for grades K-8 that integrated the disciplines and focused on major concepts that would be revisited at various grade levels in progressing degrees of complexity and scale. A book entitled *The Content Core* related NSTA's conception of appropriate subject matter for science, and a companion piece, *Relevant Research*, offered a theoretical and research-based rationale for curriculum restructure of this nature. These efforts were supported by NSF and NSTA, but since the conclusion of NSF support the project has not been able to attract substantive national attention to implementation plans. NSTA now works with publishers to develop textbooks that the organization hopes will facilitate curriculum restructure and integration.

- NSF Systemic Initiative grants to states, cities, and rural areas have been providing millions of dollars

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in matching support for systemic change in science education on state to local scales. It is too early to determine if the combination of these efforts nationally will result in strengthened programs that are considerably different from the traditional curriculum, but they have certainly had an opportunity to involve more teachers in their implementation than those national projects that to date have primarily sought demonstration sites.

• National Standards for Science Education (NRC, 1994 draft) is the National Academy of Science's attempt to develop guidelines for science curriculum restructure and systemic change. Not only do the National Standards include science content standards that express need for integration of disciplines, fewer topics in greater depth, and articulation across grade levels, they also provide guidelines for restructuring the teaching of science, the environment for science in schools, and assessment of science learning. The Standards are emerging in 1995 as the most comprehensive and perhaps most esteemed of the restructure guidelines.

In much of the discussion of what science belongs in the curriculum for all students, the Earth sciences have been slighted (Mayer, et al., 1992). In response to this, and with the firm belief that all of science is involved with understanding planet Earth, the Earth Systems Education (ESE) efforts have emerged as a grassroots mechanism for internally changing what is taught in science K-12.

Earth Systems Education takes its name from NASA's vision of Earth System Science (Earth System Science Committee, 1988), an idea that all of Earth's subsystems, the hydrosphere, lithosphere, atmosphere and biosphere, interact and change over time in ways that preclude study of one without consideration of the others. This is particularly true in the ways those subsystems respond to human activities and in return, impact them. Integration of the sciences, then, is key to understanding all Earth characteristics and processes. ESE is education's approach to Earth System Science. All of science is seen as a means of understanding Earth (Mayer, 1991).

Earth Systems Education is guided by a framework of seven Earth Systems Understandings (Figure 1) developed by a core advisory group of scientists, teachers, and science educators. The Understandings incorporate science process, subsystem interactions, the construct of change over time, and Earth's place as a subsystem of the Universe. They also incorporate reasons for the study of Earth: aesthetics and values, careers and interests, and the responsibility for stewardship.

Figure 1. Framework of Understandings that guide Earth Systems Education

1. Earth is unique, a planet of rare beauty and great value.
2. Human activities, collective and individual, conscious and inadvertent, are seriously impacting Earth.
3. The development of scientific thinking and technology increase our ability to understand and utilize Earth and space.
4. The Earth system is composed of the interacting subsystems of water, rock, ice, air and life.
5. Earth is more than 4 billion years old and its subsystems are continually evolving.
6. Earth is a small subsystem of a Solar system within the vast and ancient universe.
7. There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

Initiating Earth Systems Education

The goal of Earth Systems Education is to infuse Earth systems concepts throughout the curriculum at all grade levels, K-college. The approach taken by leaders in this effort has been to rely on teachers, for experience demonstrates that teachers can implement lasting change by believing in the need and becoming part of the process. The top-down approaches of major curriculum restructure programs have great visibility and political power because of the entities sponsoring them, but unless teachers accept the proposed changes and their role in those changes, the efforts will fall short of their potential.

ESE, then, has been propelled through teacher enhancement programs both at the origin (The Ohio State University) and in other parts of the country. Summer workshops, leadership opportunities for teachers, and networking have begun to result in grassroots changes in participants' schools.

In 1990 the National Science Foundation funded a three-year project entitled "Program for Leadership in Earth Systems Education," with the acronym of PLESE. The principal program components were intensive three-week summer workshops designed to

- provide teachers in grades 4-12 with up-to-date information on global change issues,
- acquaint them with constructivist learning approaches so they could effectively help learners to acquire science knowledge,
- equip teachers with integrated Earth systems activities that they could use in their own teaching, and
- help teachers develop skills to conduct their own workshops, thus extending the reach of the project to others in participants' local education environments.

Teachers were recruited in five-person teams to attend workshops with others from their region of the country. Teams were to consist of a teacher in each grade level - elementary, middle and high school - plus a college teacher and a school administrator from their area who could serve as facilitators for the teachers' follow-up work with the project. The three teachers participated together for three weeks in a workshop either at The Ohio State University (OSU) in Columbus, Ohio (for those in the Northeast, Southeast, and Great Lakes regions) or at the University of Northern Colorado (UNC) for those in the Pacific or Midcontinent regions (Table 1). The administrators and college liaisons for these teams joined the teachers for a three-day period near the end of the workshop. Over the course of the project, fifty-eight teams with teachers representing 36 states participated in the summer workshops.

Table 1. Teams participating in PLESE workshops by region and year.

Year	Region	States represented*	Teams	Teachers	Site
1990	Great Lakes	OH, MI, IN, IL	7	21	OSU
1991	Northeast	ME, VT, MA, MI, OH, WA, NY,	12	40	OSU
	Pacific	CA, OR, WA, HI, AK, ID, NM, AZ, CO	12	34	UNC
1992	Southeast	FL, NC, SC, MS, VA, TN, DE, NB	13	37	OSU
	Midcontinent	TX, LA, MO, KS, NB, OK, CO, SD, IA, NV, ID	13	39	UNC
1993	All (veterans)		NA	29	UNC

*** Some states appear more than once because accepted teams were accommodated when and where it was possible to place them.**

During the workshops, college faculty from the lead institutions, along with local teachers who had demonstrated leadership capability and interest in curriculum restructure, provided experiences focused on the workshop goals. For up-to-date science, each workshop had the services of three to four leading scientists who agreed to spend the same four days with participants as the teachers studied about the scientists' specialties. In cooperative learning sessions (jigsaw method) teacher groups first learned about the science topic through selected articles and a scientist, then taught the topic to teachers at their own grade level with the scientist in attendance. Over three days the teachers and scientists learned from each other. The scientist was able to see how teachers understood and planned to use the information, and the teachers came to trust the scientist as a person and their peers as teachers (Mayer, Fortner and Hoyt, submitted).

While science updates occupied most of the first week of the workshop, the work of the second week was also introduced at that time. Teachers from the same local team were to work together on development of a resource guide that would include exemplary ESE-type activities and reference materials designed to answer questions about an Earth system topic in relation to the framework of Understandings. The development of the advance questions was critical to this effort. Those who believe in ESE as a model for curriculum structure are accustomed to thinking about classroom subject matter as being selected in answer to questions. If there is no question to be answered by an activity, why do it? To construct good questions, then, is to develop a curriculum design that has relevance.

In addition to giving substance to how ESE might integrate science in their classrooms, this exercise was designed to encourage articulation of subject matter across grade levels and build a team spirit by region. As in the science jigsaw, time was allotted to share resources within grade levels as well, so that all elementary teachers, for example, would become aware of exemplary materials on the range of Earth system topics being explored by all groups. Throughout this period, project staff integrated ideas for application of classroom computer technologies and demonstrated alternative assessment techniques useful in evaluating group learning.

The final week was spent in learning how to present a workshop to other teachers. While some participants were experienced in this, a large majority of teachers indicated they had never made a personal presentation to their peers before. Since the NSF funding included support for workshops to be conducted by the teachers in their home regions, it was important to assure that participants were prepared to accept that responsibility. With project staff oversight, groups of two or three teams worked together to design a three-hour workshop, which they presented to the other groups.

Figure 2. Components of summer workshops

<table>
<tr><td>Wk. 1</td><td>Wk. 2</td><td>Wk. 3</td></tr>
<tr><td>Global Science Updates and Nature of Science</td><td>Resource Guide Development and Curriculum Integration</td><td>Leadership Development and Workshop Design</td></tr>
<tr><td colspan="3">Team-building by grade level and region</td></tr>
<tr><td colspan="3">Practice in cooperative learning, alternative assessment, technology applications</td></tr>
</table>

While completion of the resource guides and plans for peer teaching were in progress, the time came for the college and administrative liaisons to visit the workshop. After briefings on ESE philosophy and methods, liaisons joined their teachers to strategize about local efforts that could be accomplished by the group in the coming year. The liaisons were able to recommend audiences and conferences that would be appropriate to reach with ESE information and ideas, and in many cases liaisons became facilitators for the work of the teacher teams. Having representation of key support groups not only assisted the teachers, but also expanded ESE ideas into other colleges and served as program outreach for other teachers in the districts represented.

Other aspects of PLESE in addition to summer workshops included a quarterly newsletter, *PLESE Note*, which originated from the OSU project headquarters and included information from the teams, updates on science and new resources available to educators, calendar of opportunities, and articles of interest in curriculum restructure. At the end of the project the newsletter was reaching over 2200 readers. This activity of the project assured that participants and other interested people could be networked for sharing supportive information. An electronic bulletin board was also established, but even as the project came to an end the number of classroom teachers with access to electronic mail was very small.

As for leadership opportunities, the project was able to support key teachers who were restructuring their own curricula as a result of PLESE to attend national meetings and represent ESE for others. Teachers were supported to regional and national meetings of NSTA, the Geological Society of America, and Coalition for Earth Science Eduation.

During the final year of the project, teacher leaders from each of the five regional workshops were invited to a final workshop at the Colorado center. This "summit" followed the same general plan of the earlier workshops, but participants were charged with developing 1) a final set of exemplary activities and guidelines for others who would choose to infuse Earth systems concepts into their curricula, and 2) guidelines and suggestions for those interested in restructuring science education in entire schools and districts. The Resource Guide for Earth Systems Education, entitled *Science is a Study of Earth*, was initiated through these efforts as a final product of PLESE that could become the beginning of curriculum restructure for others.

Evaluation

PLESE staff conducted internal formative evaluations of workshop processes and participant needs during each of the project components, as well as summative evaluation of certain aspects such as the resource guides produced by teams and the response of scientists to their experience with the workshops. PLESE also had an external evaluator that managed formal research efforts, both qualitative and quantitative, for reporting to the sponsor. That evaluator, Horizon Research, Inc. (HRI), in Chapel Hill, NC, has contributed portions of this manuscript to be shared with other researchers and practitioners. Data collection efforts are reported for the third year of evaluation and a summary interview series with selected participants from all workshops. Methods used were:

1) Questionnaires. HRI surveyed all team participants and liaisons two weeks after each summer's workshop to get their immediate impressions and plans. The survey was repeated in April of the following year to determine how ESE was being used in classes, and how the approach had been disseminated in their schools, districts and state. Survey items were statements developed by the evaluator in consultation with the PLESE leaders to match the workshop objectives and methodologies. The items invited likert-type responses of strongly agree (2) to strongly disagree (-2), with 0 meaning No Opinion. Responses to questionnaires from 1990-91 were used formatively in improvement of

workshops. Data reported here are summative, based on the 1992 workshops with 1993 follow-up, and 1994 total project assessment (Boyd, 1993, 1994).

2) Case studies of exemplary teams. The PLESE staff recommended three teams to be studied in depth for their use and dissemination of ESE. Focus group interviews lasting 1.5-2 hours were conducted with the teachers from these teams. University and administrative liaisons were interviewed in person or by phone. Other key supporters named by the teachers (parent, other administrators) were also interviewed.

3) Site visits. A representative of HRI attended several days of the summer workshops in 1990-1992, often during the period when liaisons were present. Participants were interviewed while the workshops were in progress, regarding their responses to workshop content and processes. Observations of small group discussions and informal discussions with workshop staff, participants, and liaisons contributed to the evaluation. HRI was also present for a portion of the 1993 summit workshop for summary interviews with veteran PLESE participants.

A summary of evaluations and research, matched with objectives of PLESE, is shown in Figure 3, along with the group responsible for the evaluation, HRI or PLESE.

Figure 3. Research and evaluation components of PLESE conducted by Horizon Research, Inc. (HRI) and PLESE staff.

ESE Objective	Implementation	Evaluation	HRI	PLESE
Current science	Workshops; collaboration with scientists	Participant survey,	√	√
		scientist survey,	√	
		delayed survey (1 yr)	√	
Awareness of resources	Workshops, newsletter	Team resource guides		√
		Participant survey	√	
Leadership development	Workshops	Delayed survey (1 yr)	√	
	Follow-up funding use	informal assessment		√
Local support for change	College/admin liaisons	Liaison survey	√	
	ESE resource guide	(evaluation to come)		√
Restructure potential, incl classroom practice	Follow-up workshops;	Delayed survey;	√	
	district activities	Case studies	√	√
	Modeling in workshop	Other case studies		√

A. Current science. HRI conducted a survey of participants following the OSU and UNC workshops in 1992 to gather Likert-scale opinions about the science component in which the teachers read, discussed, peer taught, and met with scientists on various topics related to global change. Of 78 participants, 56 responded, a response rate of 72%. Teachers at the end of that last workshop felt they had increased their understanding of the topics, and the combination of approaches was effective for them. Neither group of teachers would have preferred simply listening to the scientists as a mode of learning.

Table 2. Teacher opinions on global science research component of 1992 PLESE summer workshops. (N=56)

Questionnaire Item	Mean Response		
	Combined OSU & UNC N=55	OSU N=23	UNC N=33
Small group discussions with a scientist was an important aspect of this type of learning activity	1.67	1.68	1.67
Lectures by the scientists helped me to better understand topics of global change	1.47	1.67	1.33
Approach was an effective way for me to learn about the science topics	1.28	1.20	1.33
Have used a collaborative learning model in the past with my students	1.28	1.32	1.24
Approach gave me a good understanding of how earth scientists work in solving problems dealing with the Earth System	1.22	1.24	1.21
Plan to increase my use of collaborative learning as a result of this workshop	1.07	0.92	1.18
Now have a better idea of how the descriptive/historical approaches of earth scientists differ from the techniques of the physicist and chemist	1.03	0.92	1.12
Would like to learn science content in the future using this type of collaborative learning	1.02	0.92	1.09
I thoroughly read the article prior to the discussions of the science topics	0.91	1.20	0.70
Reading the article helped me understand my science topic	0.86	0.68	1.00
Peer teaching component was an effective way to help me understand the concepts discussed by the scientists	0.86	0.92	0.82
Would have understood the topics more clearly if all the available time was used by the scientist lecturing to the entire group	-0.53	-0.60	-0.48

Strongly Agree = 2; Agree = 1; No Opinion = 0; Disagree = -1; Strongly Disagree = -2

The PLESE staff surveyed the scientists after the workshops at OSU and found that they were very pleased with the teachers' responses and level of interest in the topics, and wished they could work with more people on the informal learning approach used in the workshops. All scientists felt that working with teachers was time well spent. Most indicated they learned a great deal about teachers' instructional situations and how they approach new science, i.e. "how can I use this with my class?"

B. Awareness of resources. Two types of experiences were available to PLESE participants as a means of identifying new materials for teaching: development of the resource guides by workshop teams, and reading the PLESE Note newsletter. The newsletter was not formally evaluated, although a number of former readers have now noted its absence with some disappointment. As for the development of the resource guide, this was a perplexing task for many teachers as they tried to confine their searches to resources that would help students answer definite preestablished questions. Apparently there is an alternate approach used more frequently: find a great resource or activity, then figure out how to use it!

HRI's survey included questions related to use of the ESE Framework and development of the resource guides (Table 3). It is evident that the UNC workshop participants were more satisfied with this experience than were those at OSU, probably because the teams worked better together at UNC (Item 5). The greater UNC satisfaction could also reflect the amount of material available to search at OSU, which was considerably greater than the curriculum library at UNC and may have appeared to be an insurmountable obstacle. At UNC the materials were selected for participant use and were fairly targeted because acquisition was done with the project in mind, while at OSU the global change curriculum library dates to the mid-1980s and has materials of varying utility for the project. At any rate, both groups clearly prefer choosing their own materials rather than being handed a curriculum from the top down (last item).

Table 3. Teacher opinions on Earth Systems Framework and philosophy/development of the team resource guide. (N=56)

Questionnaire Item	Mean Response		
	Combined OSU & UNC N=55	OSU N=23	UNC N=33
Work on the Resource Guide helped me understand and internalize the Seven Understandings	1.55	1.40	1.67
I plan to integrate Earth Science into my science teaching more this year as a result of PLESE workshop	1.40	1.16	1.58
We ended up with a good topic that will be useful to me	1.37	1.28	1.44
The ESE approach is a good way to organize the science curriculum for the grade levels I teach	1.29	1.04	1.48
Area team members worked well together in developing questions and searching for materials	1.28	0.96	1.52
Questions the team developed for the Understandings will be useful in teaching classes about the Earth System	1.07	0.76	1.30
I located new activities and teaching material while working on the Guide	1.05	1.00	1.09
Working with teachers of the same grade level was useful for me	1.02	1.16	0.91
I would like to make changes in my school/district curriculum based on the work done on the Resource Guide	0.97	0.72	1.15
I plan to integrate science with other subjects more this year as a result of this workshop	0.95	0.84	1.03
The focus on one topic overly restricted the search for activities that I personally would like to use	-0.45	-0.32	-0.55
Collaborative approach to curriculum decision-making is new to me	-0.81	-1.08	-0.61
Identifying a topic for the Resource Guide was very frustrating	-0.91	-0.80	-1.00
Personality problems between some members impaired the teams' ability to work together effectively	-1.02	-0.75	-1.21
Would have been more effective if I had done the work on the Guide alone	-1.03	-0.80	-1.21
Would have difficulty incorporating the ESE Philosophy into my curriculum	-1.19	-0.76	-1.52
Would rather be told what to teach by a science supervisor, curriculum committee or other expert	-1.54	-1.60	-1.50

Strongly Agree = 2; Agree = 1; No Opinion = 0; Disagree = -1; Strongly Disagree = -2

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The PLESE staff at both UNC and OSU guided and formatively evaluated the resource guides and the process of developing them through mixed-level groups. As noted above, the development process was sometimes frustrating to teachers who were encountering excellent materials but having to focus their attention on meeting the demands of the instructional questions they had developed, rather than having time to explore at will. Most teams eventually became comfortable with the process, and expressed understanding of why the questions were the focus of the search.

OSU received and reviewed all of the team resource guides from all workshops. The products were informally evaluated based on

- appropriateness of questions
- articulation across grade levels
- variety of materials included
- justification of inclusion based on guidelines provided (number of subsystems included in the resource, number of ESUs addressed, etc.
- complete citation for easy reference.

Reviewers noted that teachers tended to return to the same sources again and again, without exploring available new avenues. In some cases, it was clear that teachers did not have very high standards for instructional value, so that an activity could be included just because it was fun or flashy, regardless of its value for answering an important question. PLESE staff note that with more time available and with more personal assistance, it should be possible to lead teachers to identify good activities that are not just "fillers" for the class day.

C. Leadership development. A delayed opinion and activity survey was conducted by HRI one year after the last team workshops (Table 4). Questionnaires went to all 178 teacher participants from 1990-92; 122 responded for a response rate of 69%. Responses indicated very promising activities were underway in a number of regions, and teachers were sharing ESE ideas with others as hoped. At the time of the survey, only one teacher from the 1992 teams indicated that her school district was actively using ESE in restructure. This will be discussed further in E. Restructure Potential.

Interviews conducted by HRI (Boyd, 1994) indicate that

> "Despite the fact that it had been several years since their participation in PLESE summer workshops, about a quarter of the teachers reported that their teams were still working together and plan to do so in the future. In addition to the team's efforts, teachers reported working on their own to disseminate the Earth Systems approach: two-thirds of the teacher reported that they had conducted Earth Systems activities on their own (apart from their team). The majority also said they plan to continue to disseminate the Earth Systems model as an individual through workshops and other activities" (p. 8).

Other teachers reported in the interviews that

> "because of their involvement in PLESE, they were given new opportunities to participate in curriculum restructuring efforts at the state and district levels, including creating new guidelines on what students should know at various grade levels. Teachers viewed these as excellent opportunities for infusing ESE, and for having a major and widespread impact."

While the classroom application of PLESE was a critical part of teachers' efforts to get ESE into schools, workshops and presentations were to serve as the vehicle for expanding ESE beyond the schools to districts, regions, and states. Team leaders were asked on spring 1993 questionnaires how many

workshops their team had conducted, the length of the workshop, target audience, and grade levels of participants. The nineteen responding team leaders (out of 26) reported a total of 72 workshops that reached over 2000 teachers; workshop participants were fairly evenly divided among elementary, middle and high school teachers (Boyd, 1993). The average length of a workshop was about 2.5 hours. A few of the teams also reported conducting workshops for administrators. Teams typically conducted more than the two workshops required to receive graduate credits for participating in PLESE. Fourteen of the 19 responding leaders in 1993 reported giving at least three workshop, with nine teams conducting 4-6 workshops apiece.

The PLESE office hears from some teams regularly with reports of new attempts to generate interest in ESE among others because of the values they have gained from it.

Table 4. Teachers' post-project report of dissemination of the Earth Systems Education model. (N=122)

Questionnaire Item	Percent of teachers who strongly agreed or agreed with statement	Mean response of teachers
In addition to my team's workshops, I have shared Earth Systems topics informally with other teachers in my school and/or district.	93	1.18
An Earth Systems resource guide or "curriculum" would be helpful in terms of wider dissemination of this approach.	84	1.29
Teachers with whom I have shared the Earth Systems Education model have responded favorably to the approach.	75	.91
Our workshops were effective in generating awareness of and interest in the Earth Systems Education model in my district and/or state.	68	.77
As an individual, I plan to continue to disseminate the Earth Systems Education model through workshops and other activities.	65	.69
I have conducted workshops and been involved in other Earth Systems activities on my own (apart from my team).	65	.48
My school administrators have provided little support for my involvement with PLESE.	29	-.35
Our team continues to work together in disseminating the Earth Systems Education model and plans to do so in the future.	23	-.50

Mean response: Strongly Agree = 2; Agree = 1; No Opinion = 0; Disagree = -1; Strongly Disagree = -2

D. Local support for change. HRI interviewed the teachers a year after the 1992 workshop with regard to their interactions with the college and administrative liaisons (Boyd, 1993). Teacher leaders on the teams averaged five in-person meetings with their liaisons, and nine additional communications with them through phone, e-mail, or other methods during the 1992-3 school year. Teachers generally found their administrative liaisons supportive of their efforts, but were less likely to report that their college liaison had been active in the team's efforts to disseminate ESE. Similarly, teachers were more likely to express satisfaction with the support provided by administrative liaisons than with than provided by the college liaisons. In open-ended responses, a few teachers cited lack of college liaison support as a deterrent to their efforts.

Types of liaison assistance mentioned by teachers included providing release time, using Eisenhower Act funds for workshops, planning workshop logistics and presentations, and offering "encouragement, information, and new activities." Liaisons gave other examples of how they had worked with their teams, including setting up workshops at state conferences and for preservice teachers, and informing state and university science educators about ESE. Several university liaisons mentioned creating or trying to create a college level ESE course; several had brought in PLESE teachers to their classes as guest speakers; one was writing an NSF proposal that would incorporate ideas from ESE into a statewide project. In one state, a grant awarded by the State Systemic Initiative program to the PLESE team had covered additional travel and materials costs. Administrative liaisons reported that ESE was an effective way to restructure curriculum and about a third of those responding to questionnaires said that they were in the process of reorganizing their school or district using the ESE model. Both college and administrative liaisons reported that their colleagues had been supportive of ESE (Boyd, 1993).

While it is likely that the responding liaisons were more actively involved in PLESE than their non-responding counterparts, virtually all of the liaisons who returned questionnaires reported that their team had worked well together and that the team approach was an effective way to disseminate ESE. Most also reported having a clear understanding of their role in PLESE and planned to continue support for their PLESE teams beyond the 1992-3 school year (Boyd, 1993).

Table 5. The impact of PLESE on participants' classroom instruction. (N=122)

Questionnaire Item	Percent of teachers who strongly agreed or agreed with statement	Mean response of teachers
I feel that I am a better teacher as a result of my involvement in PLESE.	87	1.20
As a result of my participation in PLESE, I now try to integrate the science disciplines in my teaching.	85	1.20
I frequently include Earth Systems topics in my science teaching.	84	1.05
I frequently use aspects of the Earth Systems Understandings to guide my instruction.	84	.99
As a result of my participation in PLESE, I now try to integrate science with other subjects.	80	1.04
In my classes I frequently use information and resources that I identified through PLESE.	76	.79
My students' interest in and concern about the planet have increased as a result of my participation in PLESE.	74	.89
I have increased my use of collaborative or group learning with my students as a result of my participation in PLESE.	74	.87
My participation in PLESE had little or no impact on my teaching.	8	-1.28
I rarely infuse Earth Systems topics into my classes.	3	-1.32

Mean response: Strongly Agree = 2; Agree = 1; No Opinion = 0; Disagree = -1; Strongly Disagree = -2

Fortner & Boyd, 1995

E. Restructure potential. Closely tied to the concept of leadership development is the idea that some of the PLESE teachers would not only integrate ESE into their own classrooms but also become leaders of restructure efforts in their schools and districts. To accomplish this, the teachers must feel empowered to create change. A follow-up survey by HRI indicates this has happened for individuals in many instances (Table 5, Boyd, 1994)

In addition to the formal workshops conducted by PLESE teams, most teachers reported other kinds of activities that served to disseminate ESE. For example, most had shared ESE ideas and activities informally with teachers in their school or district; some developed summer school programs and summer camps using ESE themes; and some were asked by neighboring school systems to present ESE.

Interviews were conducted by HRI among 25 participants from the 1990, 1991 and 1992 workshops to get indications of how widely ESE was impacting curriculum. Thirteen of the interviewees were selected because they were known to be doing Earth systems outreach and integration, and twelve others were selected at random. About 2/3 of the respondents indicated that district awareness of ESE was good, but that competition from other programs was strong. The data from questionnaires (N = 122) suggest that the ESE model is finding its way into local efforts to revise science curriculum (Table 6).

Table 6. Institutionalization of the Earth Systems Education model.

Questionnaire Item	Percent of teachers who strongly agreed or agreed with statement	Mean response of teachers
I believe that the Earth Systems Education model is useful for restructuring the science curriculum in my district or state.	77	.95
I have been involved with curriculum restructuring efforts in my district or state.	77	.94
I have drawn from the Earth Systems Education model in curriculum restructuring efforts in my district or state.	68	.73
There is little awareness of the Earth Systems Education model in my state.	39	.08
There is little awareness of the Earth Systems Education model in my district.	34	-.15
Colleges and universities in my locale have infused Earth Systems topics into teacher pre-service and in-service courses.	21	-.14

Mean response: Strongly Agree = 2; Agree = 1; No Opinion = 0; Disagree = -1; Strongly Disagree = -2

Finally, HRI prepared case studies of three exemplary PLESE teams: Stark County, OH; Grove City, OH; and the State of South Dakota (Boyd, 1993). According to the report, "Three exemplary PLESE teams provided evidence of the kinds of change that can occur when teachers and liaisons are committed to ESE, work well together, and utilize existing opportunities and resources to expand awareness of the Earth systems approach. The visibility provided by the teachers' participation in PLESE and their enhanced leadership abilities resulted in opportunities to change curriculum guidelines at the district and state levels, and to work with college faculty and student teachers. While the teacher-driven, grassroots approach to disseminating ESE sometimes left the teams feeling as if they were having little impact in their states, they also appeared to have embraced a long-term commitment to the Earth systems model, and believed that, with the support of their team, they could influence the direction of science education in their states."

Additional case studies of restructure can be found in the Resource Guide for Earth Systems Education and PLESE records for the following:

Leon County, FL	All elementary grades, all county
Marysville, OH	All middle school science
Ft. Lupton, CO	City-wide K-12 infusion
Stark County, OH	County-wide curriculum restructure
Dutchess County, NY	Approved Regents course for HS
Worthington, OH	2-yr. required HS curriculum
Anchorage, AK	Elementary curriculum
Grove City, OH	All sciences, Park Street MS
Pierre, SD	SSI with Earth Systems focus
Bexley, OH	8th grade curriculum in ESE
LA County, CA	County elementary curriculum
Greeley, CO	Integrated HS units
Amenia, NY	Elementary curriculum

Conclusions

In 1993 about 30 of the participants from the previous five workshops were assembled into one working group for closure on the Resource Guide book which could be a means of disseminating ESE after PLESE funding was ended. HRI visited the workshop on site and interviewed the PLESE veteran teachers. Beyond any evaluation numbers the project could tout, the statements made by teachers in those interviews offer a summative evaluation of a successful project:

[Teachers were asked "What are the major benefits you have received from the PLESE program?"]

Teacher enhancement:

"This program has changed me completely. Four years ago I had just begun to teach science in middle school. With no serious science background, PLESE has provided an educational program for me, the inspiration to become certified in science (which I am currently working on), an enthusiastic desire to instill excitement in science to my students. I am now giving workshops in my district without hesitation,and being asked for ideas to give workshops and to attend other (which gives me a chance to talk about PLESE). I am now teaching 5-6 as well as 7-8 and have been asked to teach a semester of 3rd and a semester of 4th because our science scores are rising in the upper grades." (Cynda)

Fortner & Boyd, 1995

"PLESE has

- given me a focus in my teaching
- introduced me to wonderful places and people
- (given me) empowerment over how and what I teach
- expanded my knowledge in science and teaching
- allowed for communication with and between other excellent teachers."

Relevance:

"The real world was an important emphasis. The stigma that science is a lab technique only, has to continue to be changed. The way we restructure the curriculum needs to reflect the experience rather than knowing "stuff" especially at the elementary [level]."

Restructure:

"PLESE has made a real difference in my classroom. No longer am I concerned with children learning the "facts," but more concerned with them attaining the concepts. PLESE has helped show me what is important, both for me and my students. Through programs such as this, I am excited about the classroom once more and all the possibilities therein. By making the subject matter more relevant, I have seen that students are much more likely to incorporate it into their lives, rather than casting the meaningless memorization onto the scrap heap where so much other information has found itself. I have finally discovered what I thing good teaching is and I have PLESE, in part, to thank."

" PLESE has challenged me to look more critically at activities and units I use to draw out connections and extensions." (Gayle)

Teacher support:

"ESE is such a reasonable and logical way to look at the world and to teach and learn about it. Having a national project to lend credibility to what individual teacher are doing helps in 2 ways. It tells the teacher there are others who believe the same things, so you are probably as right as you feel. The second is it tells administrators somebody else - "experts" and people willing to put money into it - also believe it is right and this gives the teacher credibility."

"I felt the program attempted to validate the input of the educator as well as recognizing the importance of the current work being done in the field of science."

"Participating in PLESE has shown me that a small group of people can make a difference."

Science education:

"PLESE has given me a broader perspective on science education at a national and global level. It has caused me to think about the future and what direction science education is heading and how I might have an effect on that movement." (Gayle)

"PLESE has taught me how much more active in educational reform I need to be."

Science:

"Specifics I take with me include: a better understanding of the science concepts and skills; the realization of how I can infuse more science into my program." (Carla)

"PLESE has taught me how to do a river study and use a Macintosh."

"PLESE gave me positive role models in education and science. (I got) exposure to scientists, specialists and experts in the science field, research, standards, models, etc.)

"(It) introduced specialists in different fields, who have given us an excitement of theirs to share with our students: earthquakes, arctic exploration, dinosaurs, etc." (Jim)

"The chance to meet with top scientists has been a real plus for me, and I have shared their thoughts and works with my classes."

Summary of 1993 participant interviews and program (HRI)

"Three exemplary PLESE teams provided evidence of the kinds of change that can occur when teachers and liaisons are committed to ESE, work well together, and utilize existing opportunities and resources to expand awareness of the Earth Systems approach. The visibility provided by the teachers' participation in PLESE and their enhanced leadership abilities resulted in opportunities to change curriculum guidelines at the district and state levels, and to work with college faculty and student teachers. While the teacher-driven, grassroots approach to disseminating ESE sometimes left the teams feeling as if they were having little impact on their states, they also appeared to have embraced a long-term commitment to the Earth Systems model, and believed that with the support of their team they could influence the direction of science education in their states."

Implications

If Earth Systems Education were to become a force in curriculum restructure in science, it would likely do so in three phases as described by Fullan (1991):

- initiation, in which the decision is made to attempt change
- implementation, the first attempts at change, probably lasting 2-3 years
- continuation, with the changes being institutionalized.

PLESE has orchestrated a number of the factors Fullan found to be important for *initiating* curriculum change:

a) existence and quality of innovations. The ESE grassroots implementation strategies are attractive to teachers because they empower teachers to make change in the situations they know best. PLESE teachers practiced how to adapt materials to an ESE approach, and found materials they could use in the new contexts. Additional resources developed by the OSU faculty, such as the *Activities for the Changing Earth System*, facilitated the search for high-quality materials to initiate change.

b) access to information. Fullan (1991) suggests that change requires continuous personal contact with the facilitators or supporters of change. Through PLESE the teacher gained a team of like-minded colleagues, and access to PLESE staff through phone, e-mail and newsletter contact.

c) advocacy from central administration. By bringing administrative liaisons into the workshops with the teachers, a mutual understanding was fostered and collective planning was facilitated. Teachers could feel they were not alone in initiating changes.

d) teacher advocacy. Fullan reminds administrators that innovations occur day to day, and teachers need support to find the time and resources to make things happen in timely ways. PLESE is a teacher advocate, using opportunities of funding, contacts (networking) and materials to facilitate teacher activities in initiating change.

e) external change agents. These are people who can assist in initiation of innovation, whether in helping to write proposals for funding, supporting additional time for thinking, learning and collaboration, or

for serving as sounding boards for ideas. College liaisons for the PLESE teams should fill this role, as did the PLESE faculty themselves.

f) community pressure/support/opposition/apathy. Dr. Paul DeHart Hurd is fond of saying that "everybody wants progress, but nobody wants to change!" Keeping the community informed is an important proactive means of turning potential criticism into active support. No one likes surprises, especially in the education enterprise where everyone qualifies as a stakeholder. This is another big arena that can be assisted by the college and administrative liaisons.

g) new policy/funding. These may come from local, state or national level, and while they facilitate action, their mandates may not lead to real change. Response to new standards for science education, for example, could be viewed by some (for whom the status quo is comfortable) as just another top-down attempt to control what happens in classrooms. Alternatively, the new standards may be tools for demonstrating the need for desired change. The award of grants may enhance capability for change, but a sponsor may put demands on the grantee that remove some freedom to change. PLESE staff have assisted several teams in developing the support needed to pursue change beyond their own classrooms, as demonstrated in the case study of Grove City, OH.

h) problem solving and bureaucratic orientations. Districts may use change to solve problems or take advantage of opportunities. Some of both may be happening in home districts of PLESE teams.

Thus the extended and targeted variety of activities conducted by the PLESE should be facilitating for the work of teachers in the program as they initiate change.

Continuing with Fullan's (1991) model, since the initiation process has been completed, at least as far as facilitators of grassroots action can manage, implementation attempts should be in progress for those impacted by PLESE. In fact the large number of case studies cited, and the geographic range they cover, indicates that implementation is indeed happening. Not all of the PLESE teams are expected to restructure their districts' science curricula. The program goal has been to infuse Earth Systems concepts throughout the curriculum, through changes made in and by teachers. The research and evaluation regarding the program and its impact indicates that the goal has been achieved in many cases, and with continuation of outreach by its promoters in and out of the classroom, Earth Systems education may be a viable means of integrating and enriching more of the science curriculum with an understanding of Earth.

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